21st Century Networks for 21st Century Schools: Making the Case for Broadband

A collaborative effort coordinated by Tom Rolfes and Tammy Stephens

How much bandwidth does your school district need? Read on for advice on how—and why—to upgrade to broadband cost-effectively.

Attend an educational technology conference today and you will find dozens of sessions dedicated to cool new technology applications intended to engage students and improve the quality of teaching and learning, but you'd be hard-pressed to find a single session about the growth or maintenance of the transport infrastructure that makes it all work. Don't get us wrong. We are excited about the promise of new web technologies and the impact they can have on education. However, without the basic infrastructure and transport required to service these technologies, their promise will never be realized.

In this compendium article, we hope to help you build a better understanding and appreciation for "broadband" and the steps that school district administrators and chief technology officers can take to make sure – without excessive spending – that your infrastructure and Internet access keeps pace.

WHY broadband

As a nation, we need high-speed broadband networks to compete in a 21st Century global economy. In *A Blueprint for Big Broadband*, published in 2008 by EDUCAUSE, author John Windhausen writes, "A growing body of research suggests that big broadband networks stimulate greater economic development. The research shows that communities that deployed fiber networks have generally enjoyed greater job growth, economic productivity, and tax revenue."

The International Telecommunications Union compares countries' telecommunications capabilities each year, examining the number of citizens with access to broadband. As can be seen from this ITU chart, the United States' rank has been dropping steadily since 1999:

Year	U.S. International Rank Broadband Subscribers Per 100 People
1999	3rd
2000	5th
2001	7th
2002	11th
2003	15th
2004	18th
2005	19th
2006	20th

SOURCE: International Telecommunications Union (http://www.itu.int)

Other countries, including Japan, Finland, Sweden, and Canada, are surpassing the United States in providing faster broadband connections at cheaper prices to their citizens. These countries have been much more aggressive in their approach and treat broadband services as a necessary utility.

As the nation loses ground, so do our schools – adding to worries about global competitiveness in the years to come. As the State Educational Technology Directors Association (SETDA) cautions, "In order to provide students with an interactive learning environment necessary to build the high level skills essential to compete in the global economy, we need to ensure that our children have access to high-speed broadband at school."

Henry Jenkins, a researcher at MIT, warns about a growing "participation gap" in schools today – a gap that he describes in *Confronting the Challenges of Participatory Culture: Media Education for the 21st Century* as "the unequal access to the opportunities, experiences, skills, and knowledge that will prepare youth for full participation in the world of tomorrow." If students do not have adequate access to the high bandwidth Internet, we limit their opportunities to participate in a globally networked society.

The demand on school networks has never been greater and trends in the emerging technologies for K-12 schools indicate that bandwidth demands will continue to grow. Examples of the sorts of high-bandwidth applications that schools today are using to improve education include:

- Media streaming and videoconferencing;
- Distance learning – especially in rural communities that have come to rely on online learning to connect them to classes and resources not available locally;
- Web 2.0 applications, including blogs, wikis, instant messaging, social networking and other tools for collaboration and learning;
- Communities of practice and online classes to support professional development;
- Data driven instruction, in which ready access to information systems plays a crucial role in improving teaching practices and differentiating instruction;
- Online assessment and secure data submission;
- Multimedia applications that make learning engaging and relevant;
- One-to-one programs, in which students have the opportunity to learn 24/7 using Internet-enabled devices.

As *A Blueprint for Big Broadband* puts it, "The constraints that inadequate broadband connections pose are vast when considering the trend towards online high stakes testing, database management, school Web presence and communication with parents, collaborative research projects, and video streaming."

How Much Bandwidth Do You Need?

With so many voices calling for broadband access, it makes sense to stop and ask, "What is 'broadband' anyway? How much bandwidth are we talking about?" The definition of broadband – which is short for "broad bandwidth" and refers to the speed or number of simultaneous data streams that can be transported over copper, fiber, or wireless technologies – varies tremendously from one source to another. One might say that broadband is more easily defined by what it is *not*, than what it *is*. It is definitely NOT dial-up access. And, according to the FCC, which oversees a broadband initiative to help bring all Americans "affordable access to robust and reliable broadband products and services," it is not any bandwidth below 200 Kbps (kilobits per second), but may be as high as 6 Mbps (megabits per second) on up to 50 to 100 Mbps.

SETDA's June, 2008, publication, *High Speed Internet Access for All Kids: Breaking Through the Barriers*, reports that, "Many industry leaders believe that the definition of broadband needs to be increased significantly in the next few years. Most believe that the definition of high-speed broadband should be at least 10 Mbps by 2010. Others support creating big broadband networks of at least 100 Mbps. Some countries have already established goals of 100 Mbps, while other countries have established goals of 10 Gbps."

So how do schools measure up? According to SETDA, most districts in the country were connecting their school buildings at T1 speeds (1.54 Mbps) in 2007 and 2008. The report's authors explain, "With these bandwidth speeds, schools are trying to accommodate the technology needs of many concurrent users. Compared to the average household with broadband access of at least 5 Mbps, with just a few users, bandwidth in many schools is significantly lower with many more concurrent users."

Taking into account the number of users or devices that may share the delivered bandwidth is clearly crucial in a school setting. A small rural school with basic Internet use may be comfortable at T1 speeds whereas a large high school may need much higher bandwidth at 20 Mbps or greater to properly transport all of its students' applications. The U.S. Department of Education developed an online bandwidth calculator as part of its School 2.0 Initiative (*http://etoolkit.org/etoolkit/bandwidth_calculator/index*) that helps schools of various sizes predict what they will need. It prompts for the number of simultaneous users and the types of applications they will be using and calculate a school's bandwidth needs from there.

With Department of Education estimates ranging from 50 Kbps for email and Web browsing to 300 Kbps per student for desktop video, one can see that the national average access speed of 6.5 Kbps per student, as reported in *America's Digital Schools* 2008, is woefully inadequate. Furthermore, if you consider that newer applications – such as forms of IP videoconferencing that can command up to 1.0 Mbps per video channel – might require far more than 300 Kbps per student, you can understand why the authors of *America's Digital Schools* identify inadequate broadband as a "crisis in the making."

BANDWIDTH BENCHMARKING

The two most common ways to approach bandwidth benchmarking are the "observed" and the "expected" approaches. The "observed" method of bandwidth benchmarking involves using software to measure network or router traffic, usually depicted as a bar/line graph, showing outgoing bandwidth and incoming bandwidth.

The "expected" method involves a summation of all the applications and uses of IP transport and Internet access within the school day. This may include the number of students and faculty multiplied by an average Kbps/user bandwidth, added to the amount needed for special, high-bandwidth applications or projects. For example:

800-student high school with 50 faculty/staff

- 850 users x 7 Kbps/user = 5.95 Mbps
- Add 1 constant videoconferencing stream of 1.5 Mbps
- Total estimated Internet access = 7.45 Mbps or FIVE T-1s (1.54 Mbps) of Internet access

Regardless of the method used, a realistic benchmark should take into account occasional bursts of traffic, anticipated increases in simultaneous users and new applications that will require additional bandwidth in the near future.

SETDA's guidelines for districts hoping to support a technology-rich learning environment for the next 2-3 years, include:

- An external Internet connection to the Internet Service Provider of at least 10 Mbps per 1,000 students/staff (or 10 Kbps per person);
- Internal wide area network connections from the district to each school and between schools of at least 100 Mbps per 1,000 students/staff (or 100 Kbps per person).

In considering bandwidth needs, schools need to be proactive in their approach and think not only of their current needs, however, but also of emerging technologies for which bandwidth will be needed in the future. In a technology-rich learning environment for the next 5-7 years, SETDA recommends:

- An external Internet connection to the Internet Service Provider of at least 100 Mbps per 1,000 students/staff (100 Kbps per person);
- Internal wide area network connections from the district to each school and between schools of at least 1 Gbps per 1,000 students/staff (1 Mbps per person).

Strategies for Increasing Bandwidth

As Internet demand inevitably bumps up against the low ceilings in most districts, schools may find themselves paying penalties to service providers for excess utilization, losing vital information because bandwidth has been exceeded, or seeing traffic grind to a halt. At this point, your main options are to implement network management devices or software in order to make the most of current capacity or to purchase more bandwidth.

Skilled technology coordinators and network technicians have made a science out of squeezing every last bit of capacity from deficient infrastructure. They use such strategies as caching and proxy servers to maximize Internet bandwidth and traffic shaping, load balancing and packet prioritization to help ensure the integrity of the most important data transmissions—all strategies to conserve limited bandwidth and ensure that administrative applications such as student information systems and online assessment have sufficient capacity.

In addition, according to *America's Digital Schools* 2008, 67 percent of school districts reported conserving bandwidth by using a restriction policy that bars students and teachers from using certain online applications, such as streaming video. For those who believe in the power of digital technology to engage and motivate students, this not an acceptable solution. At some point, attention must be shifted from "living within our means" to a scalable, yet affordable, high bandwidth infrastructure of the sort described in the sidebar, "Installing a Districtwide Fiber Network." It is imperative that school administrators and technology officers begin planning a migration path to higher bandwidth, regardless of the size and location of their schools.

How do you get broadband connectivity and how much does it cost? Although high-bandwidth transport may be achieved through a variety of means – including DSL, cable modem, wireless, satellite, fast Ethernet over copper, or broadband over powerline (BPL) – the fastest, most reliable and most scalable solution is undoubtedly fiber cable delivering optical Ethernet. Generally, "terrestrial fiber," which runs under the ground, is ideal since it is immune from most weather-related disruptions. However, in some situations – as with natural obstructions such as rivers, urban concrete, or solid rock – the best or most cost-effective solution may involve having the fiber run above ground

In determining costs, it is important to make a distinction between transport bandwidth (capacity and speed of the fiber or other infrastructure that carries the data) and Internet access (the http traffic that is being transported). For years in school districts and still in residential settings, Internet access and transport bandwidth were one and the same, being delivered and billed through a single Internet Service Provider (ISP). More recently, in modern IP-based networks, schools are opting to purchase transport bandwidth and the amount of Internet access that rides atop the transport, separately.

"Decoupling" the Internet access from transport bandwidth has enabled many districts to tap into local, regional or statewide networks and to purchase "raw" commodity Internet at rates that have been decreasing rapidly in recent years, especially in areas that afford multiple, competitive providers. Generally, the bigger the block of Internet is purchased, the lower the unit price, which means that many schools have benefited from statewide networks and other approaches that allow education entities to aggregate their demand and pass on savings to the individual district. The commercially available rate for large blocks of aggregated Internet access today is ranging from $9 to $20 per megabit per second per month, often available through a regional or state master contract. [See "Network Nebraska: How One State is Building its Infrastructure."]

Unlike Internet access costs, transport pricing has actually stayed the same or increased over time due to such factors as rising costs for construction and

INSTALLING A DISTRICTWIDE FIBER NETWORK

by Ed Zaiontz, Executive Director of Information Services Round Rock Independent School District, TX

In 2002, Round Rock Independent School District (RRISD), located near Austin, Texas, invested in a metropolitan optical fiber network to interconnect all of the schools and administrative buildings in the district. With a myriad of technology solutions from which to choose, RRISD selected an advanced fiber network to position itself for the bandwidth-intensive applications of the future.

RRISD went through a lengthy and detailed technology selection process resulting in a ring-based network architecture consisting of one super-ring containing eight nodes interconnecting with six sub-rings serving the other forty facilities in the district. RRISD's business plan was developed with the assistance of a local engineering firm that worked with district staff to secure rights of way and to consult on the overall design of the network. Cooperation with a local communications company enabled significant installation cost savings. Since the communications company's business plan called for expanding fiber into the same areas that were needed by RRISD, the cost of the proposed construction of the fiber network was reduced by 50 percent.

Technology solutions were determined based upon the size of the network, the data rates and speeds at which it was anticipated to operate, and the applications that the school district envisioned supporting. Consideration was given to network migration and operation over a 15-year period when developing the economics and business case for the build.

The innovative applications that this network has been designed to support provide remarkable education experiences for the students in Round Rock ISD as well as a myriad of previously cost-prohibitive resources for the faculty of the school district. The wholly-owned network provides over 5,000 times more bandwidth than the district's previous wide area network – which consisted of leased T1 lines – and allowed immediate utilization of streaming video and real time audio applications in daily instruction. Furthermore, the investment in the fiber network has provided substantial operating and capital equipment savings for Round Rock ISD. For example, a single centralized server in the district is used to stream video-on-demand to support instruction in the classroom. Without the fiber network, considerably more Internet bandwidth and servers on multiple campuses would be required to support the same streaming video application.

In anticipation of the opening of four new campuses for the 2008-2009 school year, the eight RRISD super-ring sites were upgraded to a 10 GB network connection, five times the capability of the original design. Future plans include upgrading campus wide-area-network switches to provide similar bandwidth at all RRISD campuses.

NETWORK NEBRASKA: HOW ONE STATE IS BUILDING ITS INFRASTRUCTURE

by Tom Rolfes, Education I.T. Manager for the Office of the CIO and Nebraska Information Technology Commission

In the late 1990s, the state of Nebraska committed significant resources to building an infrastructure to support distance learning. Beginning with "high speed" T-1 connections and eventually migrating to terrestrial fiber, the resulting network delivered analog, motion JPEG video and other content to sites all over the state.

By 2003, however, faced with expiring service contracts and a variety of incompatible and aging technologies, state leaders saw the need for a coherent, unified plan to upgrade the infrastructure to support the next generation of technology. A task force was convened to plan and make recommendations for a scalable, reliable and affordable statewide network capable of carrying a spectrum of services and applications. Approved by the state legislature in 2006, Network Nebraska is designed to connect all school districts and public colleges in the state using high-bandwidth fiber.

The multipurpose telecommunications backbone and optical Ethernet wide area networking clouds are the result of collaboration by a consortium of public entities, including the University of Nebraska, community colleges, state colleges, K-12 schools and the state's CIO. Three large aggregation points, connected to one another at speeds ranging from 500 Mbps to 1000 Mbps, act as the core routing and "choke points" for the regional Ethernet clouds, with school districts and colleges interconnecting at 40Mbps or greater bandwidth.

The goal of LB 1208, the state legislation authorizing Network Nebraska, is to have 100 percent participation. However, this is being done through incentives rather than mandates. Using $3.8 million in annual lottery funds, the state offers two types of incentive payments: equipment reimbursements for those choosing to join the network and participate in distance learning; and incentive funds for public school districts that provide courses over the network – with extra funds for those courses delivered to sparsely populated areas of the state.

Districts and colleges that join the network are charged a Network Nebraska participation fee (about $200/month) and a transport fee to help interconnect the three regions of the network (about $95/month). These costs, however, are more than offset by the savings realized on telecommunications. Through aggregated purchasing via the state master contract, the cost for Internet access to Network Nebraska customers has decreased by 98 percent over the past six years – from $803/megabit/month down to $15/megabit/month. As a result, the total amount of Internet purchased by the state's education entities has doubled several times. Each school district and college must pay for its own WAN that connects it to one of three aggregation points and these costs average about $1900/month, prior to E-rate support. For 80 percent of the districts with more economic need, the state legislature also provides about $3.4 million per year in special state aid funding for telecommunications which kicks in after their E-rate discounts.

Network Nebraska has used its Intranet routing to 230 member entities to create a statewide video LAN, or local area network, for all of its IP videoconferencing. The Network Nebraska core routers decide whether each packet of data is destined for its own regional cloud, the statewide Intranet, Internet1, or the faster Internet2. The layer 2 network allows each education entity to decide how much bandwidth should be used for Internet or other IP-based applications. For example, over 300 high school and college distance learning courses are being shared daily among its entities. Some schools conduct seven video classes per day, others only one.

Network Nebraska will be welcoming 50 new entities onto the network in the summer of 2009. Phase IV, to take place over the summer of 2010, should finish the statewide network, with 56 more school districts, almost a dozen private colleges, and a number of science centers, museums and zoos, all connected over high bandwidth fiber optic cable.

the easements frequently needed to establish fiber connectivity. The cost for broadband transport actually involves two components: NRC, non-recurring (or connection) costs and MRC, or monthly recurring costs. The non-recurring costs to establish initial broadband connectivity can vary from a hundred dollars up to many hundreds of thousands of dollars, depending upon the terrain. If a telecommunications provider needs to secure many right-of-ways through private property, cross under public thoroughfares, or trench conduit through solid rock, across water, or long distances, the price can go up substantially. However, if the telecommunications provider can reach the destination by running fiber cable above ground, the cost may be much lower. If school districts are short on up-front cash, some providers are willing to amortize connection costs over the life of the contract, adding them to the monthly recurring costs.

Monthly recurring costs for broadband transport (essentially, for the use of the "pipes" to deliver data on an ongoing basis) may range from as little as $900/month to as much as $10,000/month for 40 Mbps service. The monthly cost is greatly affected by local competition, individual-case-basis (ICB) pricing, the length of the contract term, and the proportion of the connection costs that are amortized over the life of the contract. Once they have established a high-speed, scalable fiber optic connection, schools can save some money on monthly costs by beginning with minimal levels of broadband service (e.g. 10 Mbps) and scaling up later, as needed. However, the price relationship for monthly recurring costs are not linear, meaning that the basic monthly cost for 10 Mbps may be as much as 80 percent of the cost of 40 Mbps service. Once fiber facilities are established, the circuit capacity is virtually unlimited and the unit cost per Mbps decreases.

ARRA AND BROADBAND SUPPORT

by Jon Bernstein, Bernstein Strategy Group, Legislative Consultant to CoSN

The American Recovery and Reinvestment Act (ARRA) – also known as "the stimulus" – provides more than $7 billion in new funding to support broadband penetration in unserved and underserved areas. ARRA makes funds available for those purposes through two separate programs, which are housed in two separate executive agencies: the US Department of Agriculture's Rural Utility Service (RUS) and the US Department of Commerce's National Telecommunications and Information Administration (NTIA).

$2.5 billion will flow through RUS's existing ***Distance Learning, Telemedicine and Broadband Grant program***, which traditionally provides grants, loans and loan guarantees to spur rural broadband deployment. Schools have not been a big recipient under this program, traditionally, and the program has been woefully underfunded. The statute increases the program's rural focus by requiring that 75 percent of the area served by each grant/loan/guarantee recipient's project be rural and lack sufficient access to broadband service. It also establishes a priority in awards for those relatively heavily populated rural areas that have no broadband service whatsoever. The statute also requires that the program focus on grants/loans/guarantees that lead to greater choice of broadband service providers for rural users in an effort to stimulate competition and, hopefully, more affordable prices.

Two-thirds of the available broadband funding – approximately $4.7 billion – will flow through NTIA's ***Broadband Technology Opportunities Program*** (BTOP), which the Act authorizes. Approximately $4.35 billion of the entire amount appropriated will go for grants. ARRA designates $200 million from that sum for competitive grants "to expand public computer center capacity, including at community colleges and public libraries." ARRA also earmarks another $250 million to operate a competitive grant program that focuses on funding innovative programs that "encourage sustainable broadband adoption." The remaining $3.9 billion will flow to eligible applicants through a new grant program, which the statute sets out in significant detail.

The Act tasks the Department of Commerce's assistant secretary for communications and information, in consultation with the Federal Communications Commission, with developing the new BTOP program but it sets out parameters for the program. Specifically, the new BTOP will be a matching program where applicants must provide 20 percent of the investment. Additionally, ARRA strongly urges NTIA to award at least one BTOP grant per state. Finally, it mandates strong grant recipient reporting, evaluation and accountability requirements.

ARRA carefully lays out a mission and targets for BTOP. The conference report accompanying the statute identifies BTOP's mission as: "To accelerate broadband deployment in unserved and underserved areas and to strategic institutions that are likely to create jobs or provide significant public benefits." The statute expands on the "strategic interests" language by indicating that one of the program's central purposes is to "provide broadband education, awareness, training, access, equipment and support" to, among others, schools, libraries, medical and healthcare providers, community colleges and higher education institutions. Additionally, the statute requires NTIA to make awards based on a number of factors, including whether the grant "will, if approved, enhance service for health care delivery, education, or children to the greatest population of users in the area."

However, school eligibility for grants under the new BTOP is not a sure thing. For one thing, despite the statute's identification of schools in the new program's purposes, it does not make clear that school districts are eligible applicants, stating only that an applicant must be "a State or political subdivision thereof." Although the Act does allow the assistant secretary to determine other eligible entities if he/she finds such a determination in the public interests, some Capitol Hill sources, based on the text of the statute, suggest that schools receiving E-Rate would be disfavored since grants from BTOP might be viewed as duplicative. With that said, however, a convincing argument could be made that the vast majority of schools should be eligible for BTOP because they have been unable to gain access to E-Rate's Priority II internal connections services owing to the lack of available funds.

Access to BTOP would be a boon for schools unable to gain Priority II E-Rate funding as the program explicitly allows applicants to use grants to: 1) acquire equipment, instrumentation, networking capability, hardware and software, digital networking technology, and infrastructure and broadband services; and 2) construct and deploy infrastructure related to broadband service. Moreover, it could prove especially useful to schools seeking to implement emergency notification services – support for which is not covered by E-Rate – as BTOP would allow applicants to "construct and deploy broadband facilities that improve public safety broadband communications."

Beyond BTOP, ARRA sets aside an additional $350 million for NTIA to implement a broadband data mapping study that will identify unserved and underserved areas. The Act also requires NTIA to develop a national broadband plan within one year, the goal of which is to "ensure that all people in the United States have access to broadband capability." The plan will establish benchmarks for meeting this goal and deal with issues such as delineating the most efficient mechanisms for ensuring broadband access and affordability

In order to meet the costs of a high bandwidth, fiber procurement, school districts should make full use of the Federal Universal Service Fund (the E-rate). Monthly recurring costs and non-recurring, connection costs are both eligible. E-rate support for internal LAN wiring, or Priority II funding, is reserved right now for school districts with only the highest percentages of free/reduced lunch students. School districts may also seek grants, stage a bond issue in order to raise needed resources to upgrade infrastructure, or tap into ARRA funding opportunities. (See sidebar.)

While estimates of how much bandwidth will be needed by a typical district a few years from now vary, one thing is absolutely certain—educational bandwidth demands continue to increase, often at jaw-dropping rates. K-12 technology leaders and other school and district administrators can continue to manage within their deficient T-1 infrastructure, which is a very short-term accommodation, or make plans to progress to scalable, high bandwidth infrastructure. With construction costs continuing to rise, school district decision makers would be wise to migrate to fiber optic transport as soon as possible. For districts that have already made the investment in high bandwidth infrastructure, joining a regional or statewide network or consortium offers the chance to command a lower cost of Internet access. By observing some of the suggestions highlighted in this compendium article, your school or district should be in a better position to meet the rising bandwidth demands of technology applications that promise to deliver better educational opportunities for all students. ■

For more information and links to a number of the resources referred to in this monograph, visit the CoSN Broadband Knowledge Center at: http://www.cosn.org/broadband

This publication is one of six monographs that make up the 2009 CoSN Compendium, a collection of resources for members of the Consortium for School Networking a national non-profit organization that promotes the use of information technologies in K-12 education to improve learning. Additional copies can be ordered online at *www.cosn.org*.

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